Progression of Maximum power point tracking for PV

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Abstract- *In a recent survey, Indian government has proposed to generate 20000 MW grid-based solar power, by the year 2020. To utilize the maximum power from PV panel maximum power point tracking technique is used. This paper provides a reference and gives the progression of various MPPT methods in photovoltaic power generation. The different methods for MPPT techniques are discussed. From the earlier methods to recent methods are taken from literature and dealt. Since the I-V curve of PV is non-linear the usage of power string optimizers is also explained.*

Keywords- Maximum power point tracking (MPPT), photovoltaic(PV)

I. INTRODUCTION

In recent years renewable energy sources such as solar, wave and wind are used for the generation of electricity. Photovoltaic (PV) generation is getting increasingly important as a renewable source due to the advantages such as the absence of fuel cost, little maintenance and no noise and wear due to absence of moving parts. The amount of power generated from a photovoltaic (PV) system mainly depends on the factors, such as temperature and solar irradiances. Therefore a high cost PV should be operated at the maximum power point (MPP) which changes with solar irradiances. Hence it is important to track the maximum power point of PV. There are various MPPT methods available which vary in complexity, sensors required, convergence speed, cost, range of effectiveness, implementation hardware, popularity, and in other respects.

II. PROBLEM DEFINITION

The I-V characteristics of a PV panel is shown in Fig 1. The main objective with MPPT technique is to automatically find the voltage VMPP or current IMPP at which a PV array should operate to obtain the maximum power output PMPP under a given temperature and irradiance. It is noted that during partial shading conditions, in some cases it is possible to have multiple local maxima, but overall there is still only one true MPP. Most techniques respond to changes in both irradiance and temperature, but some are specifically more useful if temperature is approximately constant. Most techniques would automatically respond to changes in the array due to aging, though some are open-loop and would require periodic fine-tuning. The array will typically be connected to a power converter that can vary the current coming from the PV array.

The aim of the paper is to provide a complete reference for MPPT methods and thereby to use power string optimizers to monitor the total output of the array and continually adjust the presented load to keep the system operation at its peak efficiency point.

III. METHODOLOGY

The main key of the study to make an attempt of solving the material handling station with the implementation of the discrete even simulation i.e. modeling the entire procedural steps exactly by using queues and the probability and statistic functions the simple model of 3 station material handling system is considered and the steps which as the intermediate process elements such as the machining centers inspection stations, packing, conveyor belts etc. are part of this study.

The aim of the paper is to provide a complete reference for MPPT methods and thereby to use power string optimizers to monitor the total output of the array and continually adjust the presented load to keep the system operation at its peak efficiency point.

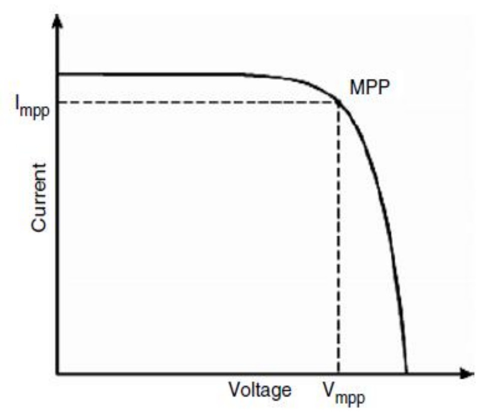

Figure 1. I-V characteristics of PV

IV. PROBLEM DEFINITION

The various MPPT methods are given in order below from the earliest.

A. Perturb & Observe (P & O) method

The most commonly used MPPT is P & O. This method is based on the criteria :- if the operating voltage of the PV array is perturbed in a give direction and if the power drawn from the PV array increases, this means that the operating point has moved towards the MPP and the operating voltage must be further perturbed in the same direction. Otherwise if the power drawn from the PV array decreases, the operating point has moved away from the MPP and therefore the direction of the operating voltage perturbation must be redressed. P&O methods can fail under rapidly changing atmospheric conditions. Fig 2 shows the flowchart for P & O method.

B. (i) Incremental Conductance (INC) method

The INC algorithm is widely used due to the high tracking accuracy at steady state and good adaptability to rapidly atmospheric condition. The incremental conductance method is based on the slope of the PV array power curve (Fig 3).

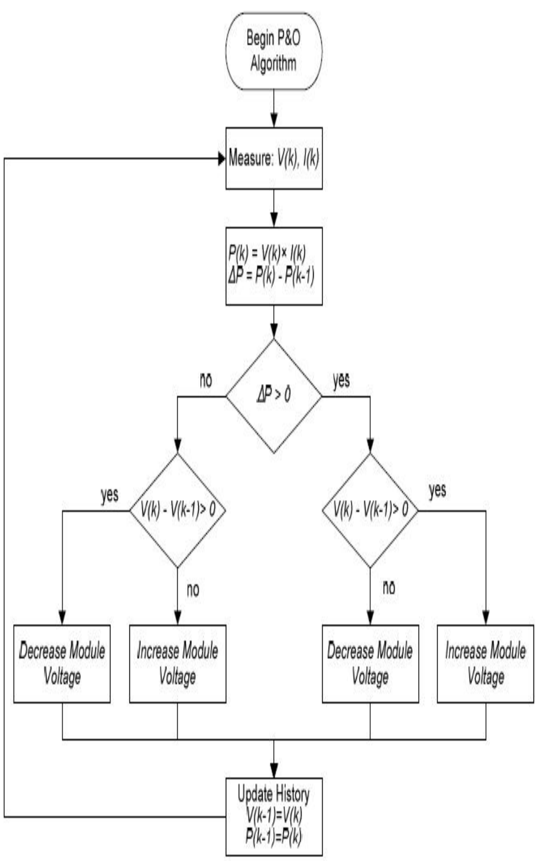

Figure 2. Flowchart for P & O

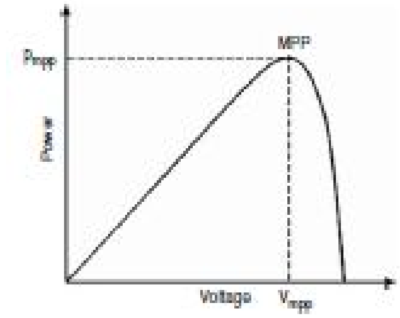

Figure 3. P-V curve of PV

If the slope is zero at the MPP, positive on the left of the MPP, and negative on the right, as given

$dP/dV = 0$, at MPP
$dP/dV > 0$, left of MPP
$dP/dV < 0$, right of MPP. (1)
(1) can be rewritten as

$\Delta I/\Delta V = -I/V$, at MPP
$\Delta I/\Delta V > -I/V$, left of MPP
$\Delta I/\Delta V < -I/V$, right of MPP. (2)

The MPP can thus be tracked by comparing the instantaneous conductance (I/V) to the incremental conductance (ΔI/ΔV). Vref is the reference voltage at which the PV array is forced to operate. At the MPP, Vref equals to VMPP. Once the MPP is reached, the operation of the PV array is maintained at this point unless a change in ΔI is noted, indicating a change in atmospheric conditions and the MPP. The algorithm decrements or increments Vref to track the new MPP. The increment size determines how fast the MPP is tracked. Fast tracking can be achieved with bigger increments but the system might not operate exactly at the MPP and oscillate about it instead there is a tradeoff.

(ii)Variable step size Incremental Conductance method

Variable step size INC automatically adjusts the step size to track the PV array maximum power point. Compared with the conventional fixed step size method, the proposed approach can effectively improve the MPPT speed & accuracy simultaneously. The step size for INC MPPT method is generally fixed. The power drawn from the PV array with a larger step size contributes – to faster dynamics but excessively steady state oscillations contributes to faster dynamics but excessive steady state oscillations resulting in a comparatively low efficiency. This situation is recessed while the MPPT is running with a smaller step size. Thus the MPPT with fixed step size should make a satisfactory tradeoff between the dynamics can be solved with variable step size iteration. This method is simple & effective way to improve tracking accuracy as well as tracking dynamic variable step size adopted to reduce the problem is

$$D(K) = D(K-1) \pm N^* \, dp/dv \qquad (3)$$

where N – Scaling factor which is tuned at the design time to adjust step size. N essentially determines the performances of MPPT system. The flowchart is shown in Fig 4

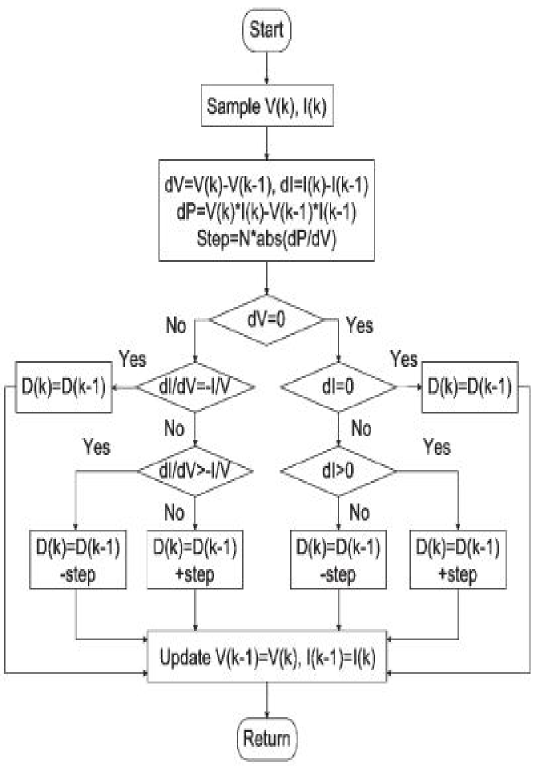

Figure 4. Flowchart for variable step size INC

C. Fuzzy control strategy

Dual mode fuzzy control strategy(Fig 6) with a regulating factor meet different requirements of accuracy and for rapidly varying atmospheric conditions.It combines rough tuning fuzzy control and precise tuning fuzzy control with regulating factor. conflict Constant voltage tracking (CVT), P&O, INC, Curve fitting method becomes difficult to achieve the level of high control accuracy, fast tracking and there is no oscillation near MPP due to non-linear characteristics of PV cells. MPPT controller with fuzzy method has good features like good robustness and adaptability, no requirements on accurate model of the object and can overcome the non linear problems of the output effectively.

To track the MPP accurately and rapidly when the working spot is far away from MPP, the controller choose the rough tuning mode. A quick tracking would be expected on the other hand, when the system works near the MPP. The controller choose the precise tuning mode, stable power output and accurate positioning would be more valuable to reduce the oscillation. Therefore rough tuning and precise tuning fuzzy control methods can be combined to form a new dual mode fuzzy control strategy. With this new strategy the output voltage and current are detected first and then the output power can be obtained. According to the output power's changes of amplitude and direction, the rough tuning mode and precise tuning mode will be chosed automatically by using the relationship between power 'P' and duty cycle 'D'. Finally, through the adjusting the duty cycle continually the output power can tend to maximum when dP/dD =0, the output power is sure to reach the maximum. Fig 5 shows the P-D relation curve.

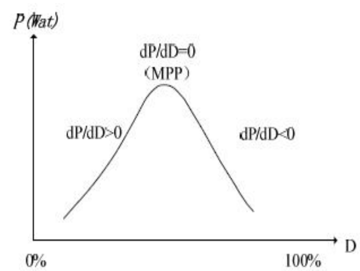

Figure 5. P-D relation curve

When K1$< \Delta\rho / \Delta D < K2$,system works in precise tuning mode, otherwise it works in rough tuning mode. Regulating factor:

$$\Delta D = [\propto \in + (1-\propto) \in C] syn\ (ECE) \qquad (4)$$

$$\Delta P(n) = E \quad \Delta P(n) \Delta D = \ EC \qquad (5)$$

$$\Delta D\ (n+1) = \ \Delta D \qquad (6)$$

Rule E is a, EC is B, $\Delta D\ is\ C$.A, B, C fuzzy subsets

D. Genetic Algorithm

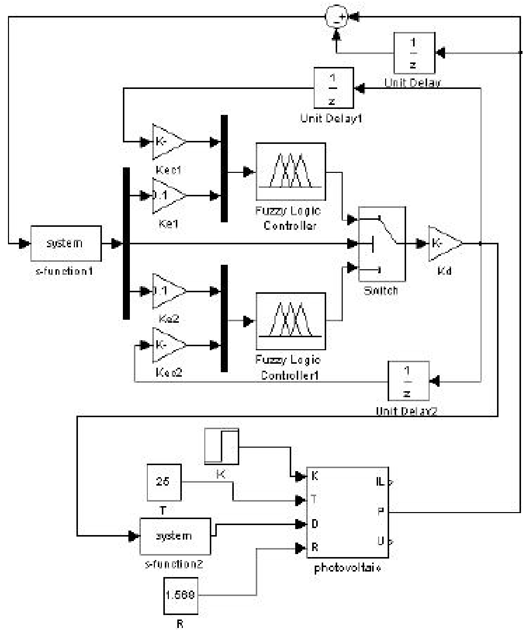

Figure 6. dual mode fuzzy control system

With GA, changes in atmospheric conditions is not exposed because the algorithm gives directly the MPP in less than one second and the data in the program change for each atmospheric condition. The oscillations around the MPP is also solved when compared with INC stability.

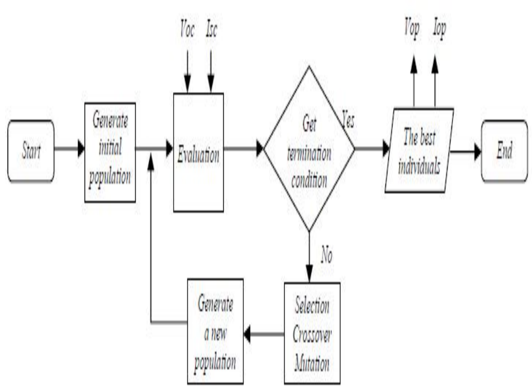

Figure 7. description of the algorithm

E. Incremental Resistance(INR) method

The primary difference between this algorithm and the others is that the step-size modes of the INR MPPT can be switched by extreme values/points of a threshold functions which is a product of the exponential of the PV array output power (Pn) and the absolute value of the PV array power derivate dP/dI as

$$C = P^n * \left|\frac{dP}{dI}\right| \quad (7)$$

This method is able to improve not only the steady state performance but also the dynamic response. The idea can be formulated by

$\Delta C/\Delta I \geq 0$, Fixed variable step-size mode (left of MPP)
$\Delta C/\Delta I < 0$, Variable step-size mode (left of MPP)
$\Delta C/\Delta I > 0$, Variable step-size mode (right of MPP)
$\Delta C/\Delta I \leq 0$, Fixed variable step-size mode (right of MPP) (8)

where $\Delta C/\Delta I$ is the increment of the threshold function. The variable step-size INR method is also based on the fact that the slope of the PV array power curve(Figure 5) is zero at the MPP, positive at the left of the MPP, and negative at the right, as given by

$dP/dI = 0$, at MPP
$dP/dI > 0$, left of MPP
$dP/dI < 0$, right of MPP. (9)

Since
(9) can be rewritten as

$\Delta V/\Delta I = -V/I$, at MPP
$\Delta V/\Delta I > -V/I$, left of MPP
$\Delta V/\Delta I < -V/I$, right of MPP. (10)

The MPP can thus be tracked by comparing the instantaneous resistance (V/I) with the INR ($\Delta V/\Delta I$), as shown in the flowchart in Figure 11. Iref is the reference current at which the PV array is forced to operate. At the MPP, Iref is equal to IMPP. Once the MPP is reached, the operation of the PV array is maintained at this point unless a change in ΔV is noted, indicating a change in atmospheric conditions at the MPP. The algorithm decreases or increases Iref to track the new MPP.

Compared with variable step size INC method, INR can greatly improve the MPPT response speed and accuracy at steady state simultaneously. Moreover, it is more suitable for practical operating conditions due to a wide operating range. The variable step- size method solves the design problem satisfying tradeoff between the dynamic and oscillations

F. Particle Swarm Optimization (PSO)

PSO technique is widely used for Partial shading. This significantly reduce the energy yield of PV solve.PSO approach is capable of tracking global MMP under Partial shaded conditions. P& O fails to track global MPPT when irradiance changed suddenly. INC offers better tracking performances but oscillation around the MPP. It is a population based search method. Algorithm maintains a swarm of individuals (called particles) where each Particle represents a candidate solution. Particles follow a simple behavior to emulate the success of neighboring particles and its own successes achieved. The position of a particle is influenced by the best particle in a neighborhood as well as the best solution found by a particle. Particle position xi are adjusted using (Fig 8)

$$x_i(j+1) = x_i(j) + V_i(j+1) \quad (11)$$

where the velocity component, ***vi***, represents the stepsize. The velocity is calculated by

$$V_i(j+1) = wV_i(j) + c_1r_1\{y_i(t) - x_i(t)\} + c_2r_2\{\overline{y_i(t)} - x_i(t)\} \quad (12)$$

where w is the inertia weight, c1 and c2 are the acceleration coefficients, r1, r2 € U(0, 1), yi is the personal best position of particle i, and is the neighborhood best position of particle i.

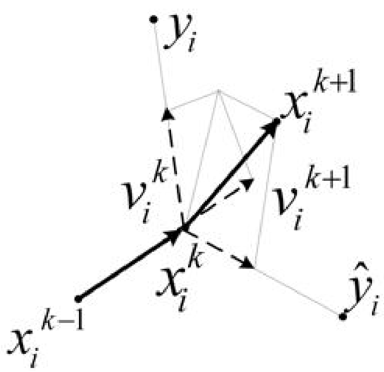

Figure 8. movement of a PSO agent

For MPPT, in a order to start the optimization, a solution vector of global current with N_p particle can be defined as :

$$x_i^k = I_g = [Ig_1, Ig_2, \ldots \ldots Ig_j] \quad (13)$$

Where j $= 1,2 \ldots . N_p$ objective function is

$$f(x_i^k) > f(y_i)$$

Where, f is the operating power of PV array.

Usually, power from PV array often changes due to partial shading. Hence, in such cases, the particles must be reinitialized to search the new global point (MPP). Therefore, following condition is used to reinitialize the particles

$$\left|\frac{Px_{(i+1)} - Px_{(i)}}{Px_{(i)}}\right| > \Delta P \quad (14)$$

PSO shows satisfactorily tracks the global point for both non shading & shading condition.

G. Estimate – Perturb – Perturb (EPP) Method

EPP is a new method (estimate – perturb – perturb) which uses one estimate process for every two perturb processes for finding maximum PV output. In this method, the perturb process conducts the search over the highly non-linear PV characteristic, and the estimate process compensates the perturb process for irradiance changing conditions. This method improves the tracking accuracy and speed of the MPPT control compared to available methods.

P&O algorithm is easy to implement it has short comings like the PV system cannot always operate at the maximum power point due to the slow trial and error process and thus the solar energy from the PV arrays are not fully utilized and the operation of the PV system may fail to track the MPP due to sudden changes in sunshine. The open and short – circuit current method is based on measured terminal voltage and current of PV arrays. It gives fast response and do not cause oscillations is steady state. The online measurement of open – circuit voltage or short circuit current causes a reduction in output.INC algorithm has fast tracking process. Fuzzy logic or neural network controls can track the maximum power point online. But these controls is the high cost of implementation.

In modified P & O method solve the climbing wrong directions by decoupling the PV power fluctuations caused by irradiance changing. This EPP method adds an irradiance changing estimate process in every perturb process to measure the amount of power change caused by the change of atmospheric condition and then compensates it in the perturb process. There are two operation mode named. Mode 1 for estimate process and mode 2 for perturb process. Comparing with the MP&O method, the EPP method, has a tracking speed of 1.5 times faster. It can provide accurate and reliable maximum power tracking performance even under a rapidly changing irradiance condition.

V. POWER OPTIMIZERS

The DC output from PV panel is converted to AC by inverters. In large scale PV, panels are connected in series to form strings and from strings parallely string inverters are connected. The drawback to this approach is that MPPT system can only be applied to the array as a whole. Because the I-V curve is non-linear, a panel that is even slightly shadowed can have dramatically lower output, and greatly increase its internal resistance. As the panels are wired in series, this would cause the output of the entire string to be reduced due to the increased total resistance. This change in performance causes the MPPT system to change the operation point, moving the rest of the panels away from their best performance. Because of their sequential wiring, power mismatch between PV modules within a string can lead to a drastic and disproportionate loss of power from the entire solar array, in some cases leading to complete system failure.

A power optimizer is a DC to DC converter technology developed to maximize the energy harvest from solar photovoltaic . They do this by individually tuning the performance of the panel through maximum power point tracking, and optionally tuning the output to match the performance of the string inverter. Power optimizers are especially useful when the performance of the power generating components in a distributed system will vary widely, differences in equipment, shading of light or wind, or being installed facing different directions or widely separated locations. string optimizers are deployed in large-scale PV systems to lower cost and increase performance. This optimized system has twice the number of modules per string and higher resolution MPP tracking than conventional systems without power optimizers. More modules per string decreases the number of combiners by 50 percent and reduces the amount of cabling which results in significant electrical balance of system savings. Putting MPPT on each string increases lifetime system production.

VI. CONCLUSION

Several MPPT techniques taken from the literature are discussed and analyzed herein, with their pros and cons. With a well-designed system including a proper converter and selecting an efficient and proven algorithm, the implementation of MPPT is simple and can be easily constructed to achieve an acceptable efficiency level of the PV modules. This paper gives a overview of all MPPT techniques and also focuses on power string optimizers which is essential for large PV panels.

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